being caused to move in a larger orbit than that described by it while still a part of the sun's mass," and the author suggests the action of comets carrying off portions of the nebulous border of a sun, as they struck it in the direction of its motion at a suitable moment.

The fifth and last article, in the results of which Dr. Smith expresses confidence other than he shows in respect of his earlier excursions into heterodox and quasi-heterodox physics, is devoted to "the laws of river-flow." Residence on the banks of the Mississippi enabled him to discover the formula of a double spiral action, by which to explain the elevation of the middle of a stream, the drift of floating material from the sides and of sunken material to the sides, the shape and depth of the eroded channels, the different speed of diverse portions of the current. This piece of at any rate unborrowed speculation appears not unworthy of consideration. H. W. B.

Das Heidelberger Schloss und Seine Gärten in alter und neuer Zeit und der Schlossgarten zu Schwetzingen. By H. R. Jung and W. Schröder. Pp. 74. (Berlin: G. Schmidt, 1898.)

IN this work we have an historical account of the gardens and castles of Heidelberg—the famous German university town, and its less well-known neighbour Schwetzingen. The authors are both gardeners, and, although the book is written chiefly from a garden point of view, a good deal of space is given to purely historical matter. Judging from the photographs, the gardens at Schwetzingen seem to be far more beautiful and natural than those of Heidelberg, where grottoes, shrines, and various other architectural devices appear to be the leading features, and not always ornamental ones either. To those interested in the history of very old and famous gardens, this treatise may be of use; and it will not take up much space on the library shelf, being only about a quarter of an inch in thickness. It is well printed and illustrated, and is practically free from misprints; the only one of any importance being at p. 47, where Azalea appears as Aralea. Were it not that there is a genus Aralia, this slip would not be worth mention.

JOHN WEATHERS.

Graduated Test-papers in Elementary Mathematics. By Walter J. Wood, B.A. Pp. 71. (London: Macmillan and Co., Ltd., 1899.)

THERE are forty test-papers in this collection, each containing questions in arithmetic, Euclid, and algebra. At the head of each test are notes stating the parts of the subjects required in order to solve the questions. The papers are primarily intended to test the progress of students preparing themselves for the examination in first stage mathematics of the Department of Science and Art, and Departmental teachers will find them of real value for that purpose. In the lower mathematical forms of secondary schools, also, the papers should be of service, as many of the questions have been selected from the papers of public examining bodies mostly favoured by such schools. Care appears to have been taken in selecting and arranging the questions, and answers are given to all the questions in arithmetic and algebra.

The Story of the British Race. By John Munro. Pp. 242. (London: George Newnes, Ltd., 1899.)

SOME time ago Mr. Munro wrote "The Story of Electricity" for this library of useful stories. In this volume he transfers his attentions to the science of anthropology, and expresses in his preface the hope that his book will "tend to destroy some errors regarding the origin and pedigree of the nation which have infected life and literature for ages." The volume should be the means of creating an interest in the study of mankind, in addition to imparting a knowledge of the nature of the races in the British Islands.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

Fourier's Series.

I HAVE M. Poincaré's authority to publish the accompanying note regarding the applicability of Fourier's series to discontinuous functions, and send it accordingly for publication in NATURE. A. A. MICHELSON.

MON CHER COLLÈGUE,—Comme je l'avais prévenu vous avez, tout à fait raison. Prenons d'abord l'integrale $\int_0^y \frac{\sin xz}{x} dx$, dont la limite pour $y=\infty$ est $\pi/4$, 0, $-\pi/4$ selon que z est positif, nul ou négatif.

Faisons maintenant tendre simultanément z vers o et y vers l'infini de telle façon que zy tende vers a. La limite sera $\int_0^a \frac{\sin x}{x} dx$ qui peut prendre toutes les valeurs possibles depuis 0 jusqu'à $\int_0^\pi \frac{\sin x}{x} dx$.

Si nous prenons maintenant n termes dans la série $\Sigma \frac{\sin kz}{z}$ en faisant tendre simultanément z vers o et n vers l'infini de telle façon que le produit nz tende vers a, cela sera évidemment la même chose; et la différence entre la somme et l'integrale sera d'autant plus petîte que z sera plus petît. Cela se voit aisément. Tout à vous,

(Signed) POINCARÉ.

A Note upon Phosphorescent Earthworms.

IT has been long known that earthworms may be phosphorescent. So long ago as 1836 Prof. Dugès described, under the name of *Lumbricus phosphoreus*, a worm which showed this peculiarity. In 1887 Prof. Giard showed that a worm probably identical with this, and, if so, not a *Lumbricus* at all, was marked luminous, especially when the soil was disturbed in the vicinity. Giard named the species *Photodrilus phosphoreus*. It has been met with and noticed to be luminous by two other observers. Quite recently (*Zoolog. Jahrbücher*, xii., 1899, p. 216) Dr. Michaelsen, of Hamburg, ascertained that this species of Giard is really identical with *Microscolex modestus* of Rosa. The multiplication of names is hardly the fault of Prof. Giard, since the genus *Microscolex* had only been instituted a few months before his genus *Photodrilus*. This species, unlike the majority of its congeners, which are chiefly congregated in Patagonia, and there very abundant, is not only European, but also occurs in England. It seems also to be, at least usually, phosphorescent. I received some time since, through the kindness of Mr. Carleton Rea, a few small earthworms from the neighbourhood of Worcester, which were undoubtedly a *Microscolex*, and at least not much different from *M. modestus*. Mr. Rea informed me that they were phosphorescent, with a "light emitted exactly similar to that of the glow-worm." They could be stimulated to show this light by "stamping the lawn." It has been suggested that this phosphorescence in earthworms is really due to photogenic bacteria entangled in the slime upon the skin. Possibly such an explanation may account for the occasional phosphorescence of *Allolobophora foetida* (the "Brandling"), observed by Vejdovsky. But the regularity, and the mode of excitation, of the luminosity seems to show that *Microscolex* is phosphorescent in its own right.

FRANK E. BEDDARD.

ON THE CHEMICAL CLASSIFICATION OF THE STARS.[1]

IN the attempts made to classify the stars by means of their spectra, from Rutherford's time to quite recently, the various criteria selected were necessarily for the most part of unknown origin; with the exception of hydrogen, calcium, iron, and carbon, in the main chemical origins could not be assigned with certainty to

[1] By Sir Norman Lockyer, K.C.B., F.R.S. A paper read at the Royal Society, May 4.

the spectral lines. Hence the various groups defined by the behaviour of unknown lines were referred to by numbers, and as the views of those employed in the work of classifying differed widely as to the sequence of the phenomena observed, the numerical sequences vary very considerably so that any coordination becomes difficult and confusing.

Recent work has thrown such a flood of light on the chemistry of the stars that most definite chemical groupings can now be established, and the object of the present communication is to suggest a general scheme of classification in which they are employed, in relation to the line of cosmical evolution which I have developed in former papers communicated to the Society.

The fact that most of the important lines in the photographic region of the stellar spectra have now been traced to their origins renders this step desirable, although many of the chemical elements still remain to be completely investigated from the stellar point of view.

The scheme is based upon a minute inquiry into the varying intensities, in the different stars, of the lines and flutings of the under-mentioned substances :—

Certain unknown elements (probably gaseous, unless their lines represent "principal series") in the hottest stars, and the new form of hydrogen discovered by Prof. Pickering (which I term proto-hydrogen for the sake of clearness). Hydrogen, helium, asterium, calcium, magnesium, oxygen, nitrogen, carbon, silicium.

Iron, titanium, copper, manganese, nickel, chromium, vanadium, strontium ; the spectra being observed at the highest available spark temperatures. The lines thus observed I term enhanced lines, and I distinguished the kind of vapour which produces them by the affix proto, *e.g.* proto-magnesium, for the sake of clearness.[1]

Iron, calcium, and manganese at arc temperatures.

Carbon (flutings) at arc temperatures.

Manganese and iron (flutings) at a still lower temperature.

In a communication to the Society[2] I stated the results arrived at recently with regard to the appearances of the lines of the above substances in stars of different temperatures, and the definition of the different groups or genera to be subsequently given are based upon the map which accompanied the paper, together with more minute inquiries on certain additional points, the examination into which was suggested as the work went on.

So far as the inquiry has at present gone, the various most salient differences to be taken advantage of for grouping purposes are represented in the following stars, the information being derived from the researches of Prof. Pickering[3] and Mr. McClean,[4] as well as from the Kensington series of photographs.

Hottest Stars.

Two stars in the constellation Argo (ε Puppis and γ Argûs).[5]

Alnitam (ε Orionis). This is a star in the belt of Orion shown on maps as Alnilam. Dr. Budge has been good enough to make inquiries for me which show the change of letter to have been brought about by a transcriber's error, and that the meaning of the Arabic word is "a belt of spheres or pearls."

Stars of intermediate Temperature (Ascending Series).

β Crucis, ε Tauri, Rigel, α Cygni, [ ] Polaris, Aldebaran.

[1] *Roy. Soc. Proc.*, vol. lxiv. p. 398.
[2] *Roy. Soc. Proc.*, vol. lxiv. p. 396.
[3] *Astro.-Phys. Journ.*, vol. v. p. 92, 1897.
[4] "Spectra of Southern Stars."
[5] The spectrum of this star contains bright lines, but I show in a paper nearly ready for communication to the Society, that when these occur with dark lines, the latter alone have to be considered for purposes of chemical classification.

Stars of intermediate Temperature (Descending Series).

Achernar, Algol, Markab, [ ] Sirius, Procyon, Arcturus.

Stars of lowest Temperature.

Ascending Series.	*Descending Series.*
Antares, one of the brightest stars in Duner's observations of Class III*a*.[1]	19 Piscium, one of the brightest stars in Duner's Class III*b*.
[Nebulæ.]	[Dark Stars.]

In order to make quite clear that both an ascending and a descending series must be taken into account, I give herewith two photographs showing the phenomena observed on both sides of the temperature curve in reversing layers of stars of nearly equal mean temperatures, as determined by the enhanced lines. The stars in question are :—

Sirius (descending). }
α Cygni (ascending). }
Procyon (descending). }
γ Cygni (ascending). }

The main differences to which I wish to draw attention are the very different intensities of the hydrogen lines in Sirius and α Cygni, and the difference in the width and intensities of the proto-metallic and metallic lines in Procyon and γ Cygni.

These differences, so significant from a classification point of view, were first indicated in a communication to the Society in 1887,[2] and the progress of the work on these lines has shown how important they are.

I have based the group—or generic—words upon the following considerations.

As we now know beyond all question that a series of geological strata from the most ancient to the most recent brings us in presence of different organic forms, of which the most recent are the most complex, it is natural to suppose that the many sharp changes of spectra observed in a series of stars from the highest temperature to the lowest brings us in presence of a series of chemical forms which become more complex as the temperature is reduced. Hence we can in the stars study the actual facts relating to the workings of inorganic evolution on parallel lines to those which have already been made available in the case of organic evolution.

If then we regard the typical stars as the equivalents of the typical strata, such as the Cambrian, Silurian, &c., it is convenient that the form of the words used to define them should be common to both ; hence I suggest an adjectival form ending in *ian*.

If the typical star is the brightest in a constellation, I use its Arabic name as root ; if the typical star is not the brightest, I use the name of the constellation.

The desideratum referred has to a certain extent determined the choice of stars where many were available. I have to express my great obligations to Dr. Murray for help generously afforded in the consideration of some of the questions thus raised. The table runs as follows :—

Highest Temperature, Simplest Chemistry.

	Argonian.		
	Alnitamian.		
Ascending Series.	Crucian.	Achernian	*Descending Series.*
	Taurian.	Algolian	
	Rigelian.	Markabian	
	Cygnian.	——	
	——	Sirian.	
	Polarian.	Procyonian.	
	Aldebarian.	Arcturian.	
	Antarian.	Piscian.	

The chemical definitions of the various groups or genera are as follows :—

[1] "Sur les étoiles à spectres de la troisième classe."
[2] *Roy. Soc. Proc.*, vol. lxi. p. 182.

Argonian.

Predominant.—Hydrogen and proto-hydrogen.

Fainter.—Helium, unknown gas (λ 4451, 4457), proto-magnesium, proto-calcium, asterium.

Alnitamian.

Predominant.—Hydrogen, helium, unknown gases (λ 4089·2, 4116·0, 4649·2).

Fainter.—Asterium, proto-hydrogen, proto-magnesium, proto-calcium, oxygen, nitrogen, carbon.

Proto-metallic lines relatively thick, hydrogen relatively thin.

Crucian.

Predominant. — Hydrogen, helium, asterium, oxygen, nitrogen, carbon.

Fainter.—Proto-magnesium, proto-calcium, unknown gas (λ 4089·2), silicium.

Achernian.

Same as Crucian.

Taurian.

Predominant.—Hydrogen, helium, proto-magnesium, asterium.

Fainter. — Proto-calcium, silicium, nitrogen, carbon, oxygen, proto-iron, proto-titanium.

Algolian.

Predominant —Hydrogen, proto-magnesium, proto-calcium, helium, silicium.

Fainter. — Proto-iron, asterium, carbon, proto-titanium, proto-copper, proto-manganese, proto-nickel.

Rigelian.

Predominant.—Hydrogen, proto-calcium, proto-magnesium, helium, silicium.

Fainter.—Asterium, proto-iron, nitrogen, carbon, proto-titanium.

Markabian.

Predominant.—Hydrogen, proto-calcium, proto-magnesium, silicium.

Fainter.—Proto-iron, helium, asterium, proto-titanium, proto-copper, proto-manganese, proto-nickel, proto-chromium.

Cygnian.

Predominant.—Hydrogen, proto-calcium, proto-magnesium, proto-iron, silicium, proto-titanium, proto-copper, proto-chromium.

Fainter. — Proto-nickel, proto-vanadium, proto-manganese, proto-strontium, iron (arc).

Sirian.

Predominant.—Hydrogen, proto-calcium, proto-magnesium, proto-iron, silicium.

Fainter.—The lines of the other proto-metals and the arc lines of iron, calcium, and manganese.

Proto-metallic lines relatively thin, hydrogen relatively thick.

Polarian.

Predominant—Proto-calcium, proto-titanium, hydrogen, proto-magnesium, proto-iron, and arc lines of calcium, iron, and manganese.

Fainter.—The other proto-metals and metals occurring in the Sirian genus.

Procyonian.

Same as Polarian.

Aldebarian.

Predominant. — Proto-calcium, arc lines of iron, calcium, and manganese, proto-strontium, hydrogen.

Fainter. — Proto-iron and proto-titanium.

Arcturian.

Same as Aldebarian.

Antarian.

Predominant. — Flutings of manganese.

Fainter.—Arc lines of metallic elements.

Piscian.

Predominant.—Flutings of carbon.

Fainter. — Arc lines of metallic elements.

We may take for granted that as time goes on new intermediate genera will require to be established; the proposed classification lends itself conveniently to this, as there are no numerical relations to be disturbed.

A still more general chemical classification is the following, it being understood that in it only the most predominant chemical features are considered, and that there is no sharp line of separation between these larger groups. The peculiar position of calcium and magnesium render this caveat the more necessary.

Highest temperature.

Gaseous stars	Proto-hydrogen stars ...	Argonian.	
		Alnitamian.	
	Cleveite gas stars	Crucian.	Achernian.
		Taurian.	Algolian.
Proto-metallic stars		Rigelian.	Markabian.
		Cygnian.	——
		——	Sirian.
Metallic stars...		Polarian.	Procyonian.
		Aldebarian.	Arcturian.
Stars with fluted spectra		Antarian.	Piscian.

Lowest temperature.

The detailed chemical facts to be gathered from the definitions of the several genera indicate many important differences between the order of appearance of chemical substances in the atmospheres of the stars and that suggested by the hypothetical "periodic law." Special investigations are in progress by which it is hoped some light may be thrown on this and other points of a like nature.

THE USE OF PHOSPHORUS IN THE MANUFACTURE OF LUCIFER MATCHES.

OUR readers will be aware that about a year ago the attention of the public was specially directed to the danger which attends the use of yellow phosphorus in the manufacture of matches. Numerous cases of necrosis of the jaw were reported, and some of these occurred in factories which were supposed to be conducted on hygienic principles. There were also some cases in these factories which had been intentionally concealed from the proper authorities. The Home Office accordingly requested Profs. Thorpe and Oliver to inquire and report upon the subject, and shortly afterwards these authorities were joined by Dr. Cunningham, senior dental surgeon to the London Hospital, in view of the importance of the practical dental question at issue.

These three gentlemen have now presented their report, and it has been issued (January 1899) as a Blue Book of 236 pages. It is to be hoped that the Government will see their way to act promptly on the recommendations here set forth, and that by a proper system of inspection they will provide for the carrying out of the new regulations; many excellent rules for the management of match factories already exist, but in some cases these have become practically a dead letter, as they have not been enforced sufficiently stringently.

We have nothing but praise for the way in which the three investigators have carried out their work. Prof. Thorpe deals with the question from the chemical standpoint, and enters into such matters as the differences between the allotropic forms of phosphorus, the composition of phosphorus fumes, their solvent action on teeth, and the composition of the various pastes, &c., used in the manufacture of matches. Full and illustrated accounts of the process of manufacture are given, both in this and in other countries, and the precautions taken to minimise the danger to the workpeople. Dr. Oliver, whose work in connection with other dangerous trades is so well known, approaches the question from